Performance Analysis for Fuel Cells:→

Fuel and oxidant flow under steady flow from surroundings. The chemical equations that describe this reactions is

Fuel + oxidizer = Products

From 1st law of Thermodynamic – $\Delta Q - \Delta W = \Delta H + \Delta(KE) + \Delta(PE)$

The steady flow energy can be written as

$$Q - W_{st} = \Delta H$$

where Q – Heat transferred from the surroundings to the system

W_{st} → work output

ΔH → Change in enthalpy for the reaction often called heat of reaction

$\Delta(KE)$ & $\Delta(PE)$ – change in kinetic and potential energy

Neglecting the $\Delta(PE)$ & $\Delta(KE)$

From IInd law of thermodynamics

$$Q = T \cdot \Delta S$$

The electromotive force that will drive electrons liberated at the anode through the external load is proportional to the Gibbs free energy change

$G = H - TS$ ⇒ ⇒ $Q - W_{st} - T\Delta S = T\Delta S - W_{st} - T\Delta S$

$$\therefore \Delta G = \Delta H - T(\Delta S) \quad (kcal/mole)$$

On substituting in eqn we get

$$\therefore (W_{st})_{max} = -\Delta G$$

efficiency $\eta = \dfrac{\text{work output}}{\text{energy supply}}$

$$\eta = \frac{(W_{st})}{-\Delta H}$$

Its maximum efficiency $\eta_{max} = \dfrac{(W_{st})_{max}}{-\Delta H} = \dfrac{-\Delta G}{-\Delta H} = 1 - \dfrac{T\Delta S}{\Delta H}$

e.m.f. of a Fuel Cell:→

The electromotive force of a fuel cell that will drive electrons through the external load is proportional to the change in Gibbs free energy during the electro-chemical reaction. it is given by

$$E = \frac{-\Delta G}{n \cdot F} \Rightarrow \Delta G = -nEF$$

where E - Theoretical electromotive force

ΔG - Change in Gibbs free energy

n - Number of electrons per molecule of reactant.

F → Faraday's constant = 96487 Coloumbs/gram mole

Here

$$\eta_{max} = \frac{\Delta G}{\Delta H} = -\frac{nEF}{\Delta H} = \frac{I \cdot t \cdot E}{\Delta H}$$

where I is the current which flows through the cell in time 't' Seconds

The actual voltage V of fuel cell attained on load will be less than theoretical voltage E developed.

Thus the actual efficiency of the cell will be less than the maximum efficiency of the cell due to loss factor

Total losses = $E - V$

Voltage efficiency $\eta = \frac{V}{E}$

maximum power output of cell is given by

$$P_{max} = \frac{-\Delta G \times m}{\text{Molar mass of fuel}}$$

m = mass flow rate of fuel in kg/s

Actual Power $P = P_{max} \times \eta_{overall}$

∴ Rate of heat released $Q = P_{max} - P$